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EFFECTS OF SIMULATED OIL FIELD DISTURBANCE AND TOPSOIL SALVAGE ON *ERIASTRUM HOOVERI* (POLEMONIACEAE)

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ABSTRACT

The effects of simulated oil field disturbance and topsoil (i.e. *E. hooveri* seed bank) salvage on *E. hooveri* reestablishment were evaluated to develop effective strategies for conserving *Eriastrum hooveri* (Jeps.) Mason, a federally threatened plant. The study was conducted at two experimental sites at the former Naval Petroleum Reserve No. 1 (NPR-1), Kern County, CA. This species was initially present at Site 1 and nearly absent at Site 2. Six replications of five treatments were established simulating salvage and non-salvage of *E. hooveri* seed-laden soil before and after seed maturation and dispersion. *Eriastrum hooveri* densities were estimated in 1993 (pre-disturbance) and 1995 (post-disturbance). In this study we found that 1) surface disturbance negatively affected *E. hooveri* density for at least two growing seasons, 2) *E. hooveri* recolonized disturbed plots in two growing seasons from seed naturally dispersed from adjacent habitat, 3) topsoil salvage and respreading did not significantly affect the recolonization of *E. hooveri* on disturbed plots, 4) the timing of topsoil salvage had no effect, 5) *E. hooveri* was established at very low densities on several plots with no previous *E. hooveri* using topsoil from occupied habitat as a seed source, and 6) *E. hooveri* cover was inversely related to total vegetation cover but not to exotic grass cover.

Eriastrum hooveri (Jepson) H. Mason, is a small annual herb endemic to the southern San Joaquin Valley and southern Coast Range regions of California (Munz 1973; Patterson 1993; Moe 1995). Plants exhibit wiry stems, alternate thread-like leaves, and small white flowers arranged in dense bracteate heads (Patterson 1993; Moe 1995). The species occurs in annual grassland and chenopod scrub habitats in portions of seven California counties at elevations ranging from 50 to 910 m (Stebbins et al. 1992; Lewis 1992; CDFG 1993; Patterson 1993; Danielsen et al. 1994; Skinner and Pavlik 1994). *Eriastrum hooveri* often occurs in sandy loam soils derived from alluvial and colluvial parent material and underlying sedimentary rocks.

Habitats occupied by *E. hooveri* commonly overlie extensive hydrocarbon deposits; thus, oil and gas development and production activities have historically resulted in impacts to habitat suitable for this species. Such impacts primarily comprise soil disturbance from grading and facility and infrastructure construction activities. Although effects of oil and gas field related disturbances on *E. hooveri* were the focus of this study, the U.S. Fish and Wildlife Service (USFWS) cited impacts from agricultural development, urbanization, and water projects as the primary threats to the species' existence (USFWS 1990).

Eriastrum hooveri was listed as threatened by the USFWS in 1990 (USFWS 1990), largely in response to Taylor and Davilla's (1986) findings and the paucity of field observations during the three-year period of drought preceding federal listing. However, the results of more recent botanical surveys conducted during non-drought years showed that this species was more common and widespread than originally believed (Lyman et al. 1991; Stebbins et al. 1992; Lewis 1992, 1994). The need for its continued listing as threatened has been questioned (Lewis 1992, 1994; Willoughby 1995). Lewis (1994) suggested that the protection of large tracts of *E. hooveri* habitat on federally managed lands would ensure survival of the species. The Bureau of Land Management has submitted a proposal to the USFWS recommending the species be delisted and the USFWS has indicated that it may follow that recommendation. Currently, federal agencies continue to manage *E. hooveri* populations on federally administered lands in accordance with Section 2(c)(1) of the Endangered Species Act of 1973.

The conservation of *E. hooveri* within its range in petroleum producing areas such as the former NPR-1 (now referred to as the Elk Hills Oil Field), necessitates the understanding of the effects of oil and gas developmental activities on the species. Primary strategies recommended by the USFWS and used by the U.S. Department of Energy (DOE) to mitigate impacts to *E. hooveri* populations at the Elk Hills Oil Field included population avoidance, or, if unavoidable, salvage and replacement of *E.*

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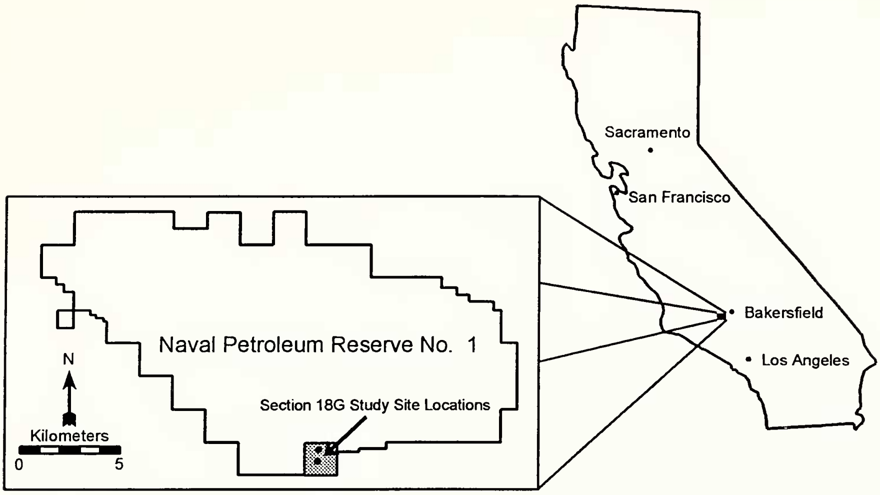

FIG. 1. Map of Naval Petroleum Reserve No. 1. Two *Eriastrum hooveri* study site locations are shown within Section 18G of the Reserve. Cartography by Mark R. M. Otten.

hooveri seed-laden topsoil. Subsequent to completion of oil field projects seed collection and reseeding was often not possible due to project timing and annual variation in *E. hooveri* seed production. Therefore, topsoil salvage and respreading following completion of the project or on nearby areas in need of habitat restoration typifies impact mitigations to this species. However, the effects of disturbance on *E. hooveri*, the effectiveness of topsoil salvage, and the effects of topsoil salvage timing were unknown. This study investigated the effects of simulated oil field disturbance on, and the efficacy of topsoil salvage for, *E. hooveri* prior to and following seed maturation and dispersion.

Entire journals are devoted to the topic of natural lands restoration and management (e.g., *Restoration Ecology, Restoration & Management Notes*) and the scientific literature has a profusion of books and articles describing the effects of various kinds of habitat manipulation on unwanted alien and desirable native and naturalized plants. Methods and results of transplanting, reseeding, and introduction of sensitive or endangered plants have been studied (Hiatt et al. 1995), especially those susceptible to poaching such as rare cacti and orchids (Lyons 1987; Allen 1994). However, except for research conducted by Holmstead and Anderson (1998) and reported in this issue, we are unaware of field trials involving experimental use of topsoil as a seed source at study sites occupied by threatened or endangered annual plants.

METHODS

The DOE conducted a manipulative field study (with USFWS approval) from April 1993 to July 1995 at the former NPR-1, 40 km southwest of Bakersfield, Kern County, CA (Fig. 1). Two *E. hooveri* study sites were located in Section 18G (Section 18, Township 31 South, Range 24 East, Mount Diablo Base & Meridian). Site 1 was about 170 m above sea level; and Site 2, located 850 m north of Site 1, was about 190 m above sea level (Fig. 2). Vegetation at both sites is characteristic of the Valley Saltbush Scrub community as described by Holland (1986). Prior to the study, *E. hooveri* was known to occur in relatively high densities at Site 1 and was believed absent at Site 2.

The regional climate is hot and dry in summer, and is cool and wet in winter with periodic fog. Annual ambient air temperatures generally range from 0–38°C (National Weather Service, no date). Annual precipitation averaged 156 mm between 1975 and 1994, occurring mostly as rain from November–April (National Climatic Data Center 1975–1995). Precipitation contributing to the growing season for annual plants (October–March precipitation) was 225 mm in 1993, 113 mm in 1994, and 227 mm in 1995 (National Climatic Data Center 1992–1995).

In the spring of 1993, thirty 6 × 30 m plots spaced 6 m apart were established at each study site. Six replications of five treatments were randomly assigned to the plots. Between April 15 and 30, the upper 5 cm of topsoil were removed from twelve Site 1 plots and saved. Using a tractor with a chisel-tooth plow and disk implements to simulate habitat disturbance from oil field-related activity, these plots and twelve Site 2 plots were ripped to a depth of 45 cm, and then disked to a depth of 15 cm. Following disking, topsoil containing *E. hooveri* was salvaged from Site 1, and then evenly spread on six plots at each site. The entire process was repeated on 12 different plots at each site in July 1993, following *E. hooveri* seed maturation and dispersion (when the topsoil presumably contained more *E. hooveri* seed). The remaining six

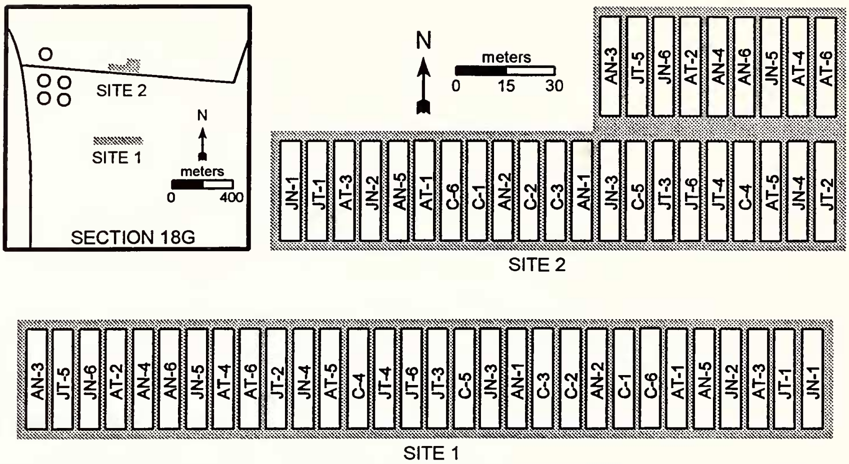

FIG. 2. *Eriastrum hooveri* study site map and experimental scheme. AN = April, no topsoil imported; AT = April, with topsoil; JN = July, no topsoil imported; JT = July, with topsoil; C = control; numbers 1–6 = replication number. Plots are 6 m × 30 m. Illustration by Mark R. M. Otten.

plots at each site were not treated, and served as controls. In summary, the treatments at Sites 1 and 2 were as follows: plots disked in April (before seed maturation) with no topsoil replacement (AN), plots disked in April and covered with topsoil containing *E. hooveri* seed (AT), plots disked in July (after seed maturation) with no topsoil replacement (JN), plots disked in July and covered with topsoil containing *E. hooveri* seed (JT), and undisturbed control plots (C).

Pre-disturbance baseline data from Sites 1 and 2 were collected in April 1993, prior to habitat manipulation. Total cover of detritus, bare ground, cryptogamic soil crust, and (vascular) vegetation cover (as defined by Bonham [1989]) by species was estimated on the plots using a tripod-mounted 10× ocular point projection device or "cover scope" (ESCO Associates Inc., Boulder, CO). *Eriastrum hooveri* density was estimated by recording the number of individuals observed in ten 0.25-m^2 quadrats sampled at 2.5-m intervals along a 25-m transect in each plot. In 1995, post-disturbance sampling was conducted during the peak of the growing season using the same methodology.

Mean pre-disturbance and post-disturbance *E. hooveri* densities among treatments on Sites 1 and 2 were analyzed using one-way ANOVA and Tukey's Studentized Range Test. Mean 1993 and 1995 *E. hooveri* densities at Site 1 were compared using two sample t-tests. Mean pre-disturbance and post-disturbance *E. hooveri* densities on Site 1 and 2 were correlated with total vegetation cover, dominant shrub cover (*Atriplex polycarpa* (Torrey) S. Watson), and dominant grass cover (*Bromus madritensis* L. ssp. *rubens* (L.) Husnot). Statistical analyses were performed using SAS/STAT v.6 software (SAS Institute Inc. 1990).

RESULTS

Pre-disturbance. Eriastrum hooveri was present on 28 of the 30 Site 1 plots prior to habitat manipulation. On a Site 2 JN plot transect, one *E. hooveri* plant was found in 1993. This plot was subsequently eliminated from the analysis to remove sample bias. Mean *E. hooveri* density was more than four times higher on the Site 1 JN plot transects before disturbance than other treatments (Table 1); however, when tested, this difference was found to be not significant because of highly variable data. *Eriastrum hooveri* density was negatively correlated with total vegetation cover, although the relationship was weak (R^2 = 0.0964; P = 0.0950). *Eriastrum hooveri* density was not related to *B. madritensis* ssp. *rubens* or *A. polycarpa* cover.

Post-disturbance. In 1995, *E. hooveri* densities were significantly lower (F = 6.91, df = 4, 29; P = 0.0007) on Site 1 disturbed plot (AN, AT, JN, JT) transects than control plot transects (Table 1). Mean *E. hooveri* densities in 1995 were higher on Site 2 JT plot transects than other treatments, but the differences were not statistically significant. One *E. hooveri* plant was present on a Site 2 control plot transect. No *E. hooveri* plants were observed on Site 2 AN and JN plot transects except on the JN plot which had been eliminated from the analysis. *Eriastrum hooveri* density was negatively correlated with total vegetative cover, but not related to *B. madritensis* ssp. *rubens*, or *A. polycarpa* cover.

Mean *E. hooveri* densities on Site 1 disturbed plot (AN, AT, JN, JT) transects were lower in 1995 compared to pre-disturbance densities, but the differences were not statistically significant. During the same period, mean *E. hooveri* density increased

TABLE 1. MEAN *ERIASTRUM HOOVERI* PRE-DISTURBANCE AND POST-DISTURBANCE DENSITIES AT SITES 1 AND 2. Density values shown are mean number of individual plants rooted within 0.25-m^2 frames sampled at 2.5-m intervals along 25-m transects. Standard errors are shown in parentheses. [1] Experimental site located within known *E. hooveri* population area. [2] Experimental site located in area with near absence of *E. hooveri* (in 1993). [3] AN = April, no topsoil imported; AT = April, with topsoil; JN = July, no topsoil imported; JT = July, with topsoil; C = control. [4] Pre-disturbance measurements. [5] Means within a column with different letters are significantly different at $\alpha = 0.05$.

	Site 1[1]		Site 2[2]	
Treatment[3]	1993[4]	1995	1993[4]	1995
AN	1.82 A[5] (0.7436)	0.85 A (0.5051)	0	0 A
AT	2.32 A (1.5372)	0.52 A (0.1956)	0	0.02 A (0.0167)
JN	11.8 A (7.7719)	1.75 A (0.8265)	0	0 A
JT	2.47 A (1.2785)	0.85 A (0.2377)	0	0.18 A (0.1641)
C	2.30 A (1.0139)	4.37 B (0.8758)	0	0.02 A (0.0167)

from 2.30 to 4.37 plants per 0.5 m^2 on Site 1 control plot transects, but again, this increase was not statistically significant.

DISCUSSION

The effects of surface disturbance on *E. hooveri* are poorly understood. A common perception held by the authors of this paper and other botanists who have studied *E. hooveri* is that colonies of this species appear to be tolerant of some undetermined level of disturbance and that the species is adapted to generally open microhabitats (e.g., Lewis 1992, 1994; Holmstead and Anderson 1998). *Eriastrum hooveri* plants are often present on previously disturbed areas (Taylor et al. 1988; Lyman et al. 1991; Lewis 1992; Holmstead and Anderson 1998), sometimes with the disturbance apparently defining *E. hooveri* colony boundaries (Lewis 1994). Lewis (1994) found that 49 of 53 *E. hooveri* sites threatened by off-highway vehicle usage were situated on previously disturbed sites. Cypher (1994) observed higher *E. hooveri* survival rates on grazed than ungrazed areas, and no difference in *E. hooveri* fecundity between grazed and ungrazed areas. Holmstead and Anderson (1998) suggested that some level of habitat disturbance is compatible with *E. hooveri* conservation. In our study, *E. hooveri* density was negatively correlated with total vegetation cover, although the relationship was admittedly weak. This is consistent with our general field observations. Many *E. hooveri* locations on and adjacent to NPR-1 are 1) naturally or artificially disturbed sites supporting early successional species, and 2) relatively open microhabitats at sites dominated by later successional species. We found no correlation between *B. madritensis* ssp. *rubens* cover and *E. hooveri* cover, so the amount of overall vegetation cover, rather than exotic grass cover, seems to limit *E. hooveri* growth.

Our results support the hypothesis that this species readily recolonizes relatively small sites subjected to simulated oil field disturbance. During the study, *E. hooveri* recolonized disturbed Site 1 plots two growing seasons after disturbance. If precipitation prior to the 1994 growing season had not been below average (113 mm versus 143 mm normal), *E. hooveri* recolonization might conceivably have occurred by the first growing season, as observed by Holmstead and Anderson (1998).

In our study, respreading of seed-laden topsoil led to the growth of *E. hooveri* at very low densities on several previously unoccupied Site 2 plots; however, *E. hooveri* densities were lower than on Site 1, probably due to the lack of seed dispersal from adjacent occupied habitat. Because of the extremely low densities that resulted, it appears that topsoil importation for the purpose of establishing *E. hooveri* on unoccupied habitat may not be an effective conservation measure.

Although *E. hooveri* reestablishment was achieved on Site 1, *E. hooveri* density was significantly lower on disturbed plots than control plots. This lower density is probably temporary because *E. hooveri* density on disturbed plots studied by Holmstead and Anderson (1998) was similar to or higher than on control plots after five growing seasons (Hinshaw unpublished). In our study, further monitoring will be needed to determine the recovery period for *E. hooveri* at Sites 1 and 2.

Eriastrum hooveri densities on Site 2 plots that received topsoil collected in July were higher than on plots receiving topsoil collected in April, but the difference was not statistically significant. This slight difference may have resulted from initially higher *E. hooveri* densities on Site 1 JN plots from which the topsoil was collected (Table 1). These data support the conclusion that timing of topsoil salvage did not affect post-disturbance *E. hooveri* densities. Apparently, seed dispersal from adjacent habitat and seeds contained in the soil seed bank contributed more to recovery than did the 1993 seed crop. Therefore, a mitigation requirement to delay oil field activities until after *E. hooveri* seed set would appear to be both ineffective and unnecessary for *E. hooveri* conservation.

Eriastrum hooveri densities on Site 1 were similar to or lower on disturbed plots receiving topsoil than disturbed plots with no topsoil. This result was unexpected because topsoil removal was equivalent to soil seed bank removal. *Eriastrum hooveri* plants on the plots with no topsoil probably resulted from seeds naturally dispersed from adjacent occupied habitat. On these plots, topsoil salvage did not appear to be an effective strategy for enhancing the recolonization of this species on relatively small disturbances. Seeds from adjacent habitat apparently dispersed onto disturbed sites, producing plants after 1–2 growing seasons. Therefore, topsoil salvage and respreading on relatively small disturbances within areas occupied by *E. hooveri* would seem unnecessary for purposes of species conservation.

Funding for future studies of *E. hooveri* is uncertain because this species apparently is slated for delisting (Warren personal communication). Should further research occur, however, we recommend that germination studies be conducted under controlled conditions to learn more about seed bank dynamics of this species. Habitat manipulation studies of the effects of flooding, fire, herbivory, and anthropogenic surface disturbance on *E. hooveri* would certainly add further insights useful in developing management strategies for conserving this species. In addition, we strongly support Lewis' (1992, 1994) contention that further field inventories are needed for this cryptic herb.

In conclusion, *E. hooveri* density was negatively affected by simulated oil field disturbance for at least two growing seasons, simulated topsoil salvage did not enhance *E. hooveri* reestablishment on disturbed plots, the timing of topsoil salvage did not affect the density of subsequent *E. hooveri* plants, and *E. hooveri* cover was not related to exotic grass (*B. madritensis* ssp. *rubens*) cover, but was inversely related to total vegetation cover.

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Literature Cited

Allen, W. H. 1994. Reintroduction of endangered plants. BioScience 44:65–68.

Bonham, C. D. 1989. Measurements for terrestrial vegetation. John Wiley and Sons, Inc., New York.

California Department of Fish and Game (CDFG). 1993. Rarefind: *Eriastrum hooveri.* California Natural Diversity Data Base. California Department of Fish and Game, Sacramento, CA.

Cypher, E. A. 1994. Demography of *Caulanthus californicus, Lembertia congdonii,* and *Eriastrum hooveri,* and vegetation characteristics of endangered species populations in the southern San Joaquin Valley and the Carrizo Plain Natural Area in 1993. Unpublished report to the California Department of Fish and Game, Sacramento, CA.

Danielsen, K. T., T. M. Austin, and C. Wong-Lee. 1994. Field inventory of *Caulanthus californicus* (California jewelflower) in Los Padres National Forest. Unpublished report to U.S. Forest Service, Goleta, CA.

Hiatt, H. D., T. E. Olson, and J. C. Fisher, Jr. 1995. Reseeding four sensitive plant species in California and Nevada. Pp. 94–101 *in* Roundy, B. A. et al. (compilers), Proceedings: wildland shrub and arid land restoration symposium. General Technical Report INT-GTR-315. USDA Forest Service Intermountain Research Station, Ogden, UT.

Holland, R. F. 1986. Preliminary descriptions of the terrestrial natural communities of California. California Department of Fish and Game, Sacramento, CA.

Holmstead, G. L. and D. C. Anderson. 1998. Reestablishment of Hoover's wooly-star (*Eriastrum hooveri*) following disturbance. Madroño 45(4):(in press).

Lewis, R. 1994. *Eriastrum hooveri* field inventory: 1994. Unpublished report to U.S. Bureau of Land Management, Caliente Resource Area, Bakersfield, CA.

———. 1992. *Eriastrum hooveri* field inventory: 1992. Unpublished report to U.S. Bureau of Land Management, Caliente Resource Area, Bakersfield, CA.

Lyman, J. C., K. Wilson, S. Bianco, B. Wunner, and G. Clifton. 1991. Botanical survey for *Eriastrum hooveri* on Naval Petroleum Reserve No. 1, Kern County, California. BioSystems Analysis, Inc. Report No. J-598 to EG&G Energy Measurements, Inc., Tupman, CA.

Lyons, G. 1987. Landscaping with extinction. Pp. 226–244 *in* D. Fuller and S. Fitzgerald (eds.), Conservation and commerce of cacti and other succulents. World Wildlife Fund, Washington, D.C.

Moe, L. M. 1995. A key to vascular plant species of Kern County, California. California Native Plant Society, Sacramento, CA.

Munz, P. A. and D. D. Keck. 1973. A California flora and supplement. University of California Press, Berkeley, CA.

National Climatic Data Center (NCDC). Bakersfield, CA. 1975–1995. National Climatic Data Center. Asheville, NC.

National Weather Service. No date. The climate of Kern County. Kern County Board of Trade, Bakersfield, CA.

Patterson, R. W. 1993. *Eriastrum.* Pp. 826 and 828 *in* J. C. Hickman (ed.), Jepson manual: higher plants of California. University of California Press, Berkeley, CA.

Sas Institute Inc. 1990. SAS/STAT user's guide, version 6. Cary, NC.

Skinner, M. W. and B. M. Pavlik (eds.). 1994. Inventory of rare and endangered vascular plants of California. Special Publication No. 1, California Native Plant Society, Sacramento, CA.

Stebbins, J. C., T. C. Mallory, W. O. Trayler, and G. W. Moise. 1992. Botanical resources report: California Aqueduct. Unpublished report prepared for the San Joaquin Field Division, California Department of Water Resources.

Taylor, D. W. and W. B. Davilla. 1986. Status survey for three plants endemic to the San Joaquin Valley and adjacent areas, California. BioSystems Analysis, Inc. Report No. J-235, U.S. Fish and Wildlife Service, Sacramento, CA.

Taylor, D. W., R. E. Palmer, G. L. Clifton, and K. A. Teare. 1988. Reconnaissance survey for federal candidate rare plants, Elk Hills Naval Petroleum Reserve No. 1. BioSystems Analysis, Inc. Report No. J-361 to EG&G Energy Measurements, Inc., Tupman, CA.

U.S. Fish and Wildlife Service (USFWS). 1990. Endangered and threatened wildlife and plants: determination of endangered and threatened status for five plants from the southern San Joaquin Valley. Federal Register 55:29361–29370.

Willoughby, J. 1995. The future of California's floristic heritage on public lands. Madroño 42(2):242–268.